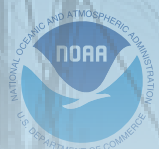


# **5** Northwest Fisheries Science Center **TH SCIENCE SYMPOSIUM**

Fisheries for the Future | April 5-6, 2016



**NOAA**  
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## Speaker & Poster **ABSTRACTS**

NOAA Western Regional Center  
7600 Sand Point Way, Building 9  
Seattle, Washington

**Presented by**

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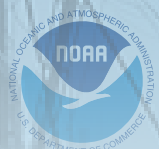
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# **5** Northwest Fisheries Science Center **TH SCIENCE SYMPOSIUM**

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# **Speaker Abstracts**

## Session 1: Habitats | Tues, April 5th | 9:10-10:40 am

### Fine-scale benthic habitat classification as part of the Northwest Fisheries Science Center's (NWFSC) Southern California Hook and Line Survey

Aaron C. Chappell\*, Curt Whitmire, John Harms, Jim Benante, and Aimee A. Keller

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The NWFSC's Southern California Shelf Rockfish Hook and Line Survey samples hard bottom habitats within the Southern California Bight via rod and reel gear to provide management information for multiple demersal rockfishes (*Sebastes* spp.). The survey, initiated in 2004, traditionally samples 121 fixed stations annually from Pt. Arguello (34.6°N) to the Mexican border (32.1°N) at depths of 37 – 229 m. To complement the fishing component of the survey, a towed camera-sled equipped with a low-light analog camera and mini-DV recording system is deployed opportunistically to collect video data on fish presence and benthic habitat. Through the 2015 survey, we have analyzed nearly 10,000 benthic habitat observations collected during 90 dives at 78 unique sites.

Benthic habitat observations were categorized both by major strata (primary,  $\geq 50\%$  of habitat in the field of view (FOV); secondary,  $\geq 20\%$  of the next most abundant habitat in the FOV; and, all other habitats in the FOV), and by eight previously-defined substrata categories: mud, sand, pebble, cobble, boulder, continuous flat rock, diagonal ridge and vertical rock-pinnacle top.

When compared with existing National Oceanic and Atmospheric Administration's Essential Fish Habitat (EFH) maps in the areas of our camera-sled tows, we found significantly different habitat classification values, especially for hard habitats. This suggests hard-bottom habitat features, especially smaller reefs, rock outcrops and boulder patches are not fully resolved within available habitat maps. Incorporating habitat designation from EFH substrate maps into the development of abundance indices or other metrics for groundfish stock assessments may misrepresent the total available hard-bottomed habitats available to many species that use them, resulting in biased estimates. Additionally, users of EFH substrate data on small-scale projects should be aware of the associated limitations.

**HABITATS**



## Using spatio-temporal models to identify drivers and trend of eelgrass in Puget Sound over the past 40 years (1972-2012)

Andrew Ole Shelton\*, Tessa B. Francis, Blake E. Feist, Greg D. Williams, and Phillip S. Levin

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Habitat-forming species such as eelgrass and algae (e.g. *Laminaria* spp., *Nereocystis luetkeana*) play a vital role in the life-history of a wide range of marine species – e.g. providing shelter for juvenile salmon, forage for migrating birds, and spawning habitat for herring. Despite the ecological importance of such foundation species, a lack of long-term data has limited our understanding of how the occurrence and abundance of these species has changed both spatial and temporally. I will present a massive data set of spatially referenced surveys of nearshore vegetation collected by the Washington Department of Fish and Game to provide the first description of spatial and temporal patterns occurrence of nearshore vegetation types in Puget Sound, Washington (1972-2012). I focus on eelgrass and show remarkable stability in Puget Sound eelgrass as a whole. However, the eelgrass trend in aggregate obscure distinct trends (both positive and negative) that occur at the local level. I will talk about spatio-temporal models and their use in identifying environmental and land use variables that may be affecting eelgrass populations.

HABITATS

## Prioritizing habitat restoration for endangered salmon: getting the most bang for your buck

Robby Fonner\*, Jon Honea, Jeff Jorgensen, Michelle McClure, and Mark Plummer

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In the Pacific Northwest of the United States, hundreds of millions of dollars are spent annually to restore upland stream habitat for salmon populations listed under the Endangered Species Act (ESA). Despite this sizable financial commitment to salmon population recovery, in practice, the restoration projects selected for implementation are often misaligned with the biological needs of endangered salmon populations. While this disconnect is partially attributable to socio-political factors, it is important that policy makers have actionable information on the relative effectiveness of candidate restoration projects. This study utilizes spatially explicit biological models and historical cost data to assess the cost effectiveness of alternative Spring Chinook habitat restoration projects in the Wenatchee River basin in Washington, USA. The biological response achieved with a fixed restoration budget varies significantly across restoration locations and activities, underscoring the importance of comparing restoration alternatives that are spatially explicit and associated with specific restoration actions. Prioritizing restoration alternatives in this framework represents a first step towards aligning restoration activities with the goals of the ESA.

HABITATS

## Persistent pollutants in Puget Sound juvenile Chinook salmon: current concentrations and long-term trends

Lyndal L. Johnson\*, Gina M. Ylitalo, James E. West, and Sandra M. O'Neill

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Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*) have been listed as a threatened species under the Endangered Species Act since 1999. Factors contributing to their decline include overharvest, hatchery impacts, and loss and modification of salmon habitats, including reduced habitat quality due to contaminant inputs. Since the late 1980s, NOAA Fisheries has been measuring concentrations of persistent organic pollutants (POPs) in juvenile salmon from Puget Sound, WA. Initial studies in 1986 and 1989 revealed unexpectedly high concentrations of polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethanes (DDTs), and polycyclic aromatic hydrocarbons (PAHs) in juvenile Chinook salmon or their prey from urban areas in the Sound. Over the following 25 years, there have been numerous efforts to reduce contamination in Puget Sound, including remediation and restoration of superfund sites in Elliott Bay, Seattle, WA and Commencement Bay, Tacoma WA, with associated assessment of contaminant exposure in juvenile salmon and other trust resources. In 2013, NOAA Fisheries and Washington Department of Fish and Wildlife conducted a joint study to measure concentrations of contaminants in Chinook juvenile salmon from five Puget Sound river-estuary systems: Skagit, Snohomish, Green/ Duwamish, Puyallup/Hylebos, and Nisqually. We report the extent and magnitude of current exposure, and compare this to concentrations measured in salmon in previous studies conducted from the late 1980s to 2006. Results indicate declines in exposure to DDTs, PCBs, and PAHs in juvenile Chinook salmon from several estuary systems, suggesting that efforts to reduce inputs of these chemicals to the Sound have had some success. However, in a significant proportion of salmon, exposure to PCBs and PAHs is still above estimated toxicity thresholds. These data establish a time series of contaminant conditions in juvenile Chinook salmon to measure the effectiveness of past and current toxics reductions strategies and actions, inform future pollution reduction efforts, and enhanced recovery of Chinook salmon.

HABITATS

## Wastewater treatment plant effluent alters pituitary gonadotropin mRNA levels in juvenile coho salmon (*Oncorhynchus kisutch*)

Louisa B. Harding\*, Irvin R. Schultz, Denis A. M. da Silva, Gina M. Ylitalo, and Penny Swanson

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Endocrine disrupting compounds (EDCs), including natural and synthetic estrogens present in wastewater treatment plant (WWTP) effluents can interfere with reproduction in fish and induce hepatic vitellogenin (*vtg*) in juveniles or adult males. The pituitary gland is a central regulator of reproduction, producing follicle-stimulating hormone (Fsh) and luteinizing hormone (Lh) that regulate gonadal sex steroid synthesis and gametogenesis. In turn, estrogens and androgens feedback and regulate Fsh and Lh. However, effects of EDCs on the pituitary gland have not been extensively investigated. Our aim was to examine effects of WWTP effluent on hepatic *vtg* and pituitary Lh and Fsh beta subunits (*lhb*, *fshb*) mRNAs in juvenile coho salmon. First, a controlled 72-hr exposure to 17 $\alpha$ -ethynylestradiol (EE2, a synthetic estrogen in oral contraceptives) and trenbolone (TREN, a synthetic androgen used in livestock production) was performed. Second, fish were exposed to 0, 20 or 100% effluent from 8 WWTPs from the Puget Sound, WA region for 72 hrs. *Lhb* mRNA levels were significantly increased in response to 2.5 or 12 ng EE2/L, and to 5 WWTP effluents. Transcript levels of *vtg* were dramatically increased in response to 12 ng EE2/L, but not to 2.5 ng EE2/L, TREN or any WWTP effluents. Mean levels of natural and synthetic estrogens in bile were higher in fish with elevated pituitary *lhb* expression, suggesting that the observed *lhb* induction may be due to estrogenic activity of WWTP effluents. These results suggest that *lhb* gene expression may be a more sensitive index of exposure to estrogenic chemicals than hepatic *vtg* under short-term exposure studies with juvenile coho salmon. Further work is needed to evaluate the utility of *lhb* induction as a potential indicator of estrogen exposure in immature salmon. This work was supported by the National Oceanic and Atmospheric Administration and US Environmental Protection Agency, Region 10.

HABITATS

## PIT tag detection system development - Lower Granite Dam spillway

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Over the past decade the Corps, BPA, and NOAA Fisheries have been developing a PIT-tag detection system for spillways. This development has to address a variety of technical challenges which include the need for a relatively large detection field, a short transit time within the detection field, shielding designs that minimizes impacts from ferrous rebar as well as adjacent antennas, and synchronization of multiple antennas. The Bonneville Dam corner-collector PIT-tag system (BCC) has been the concept design and preliminary field testing location for fish tests. During 2011, we evaluated a prototype spillway transceiver that could detect standard ISO FDX-B tags that are detected in 32 msec as well as faster non-ISO tags that are detected in 16 msec. A similar fish test was conducted in April 2014 after additional modifications were made to the spillway transceiver (FS3001) being developed by Biomark. We tagged 4,000 juvenile spring Chinook salmon with either 32-msec SST-1 12-mm tags, 16-msec SST-1 12-mm tags, 32-msec PT300 9-mm tags, or 16-msec PT300 9-mm tags. Fish were released individually at the entrance to the corner collector within the capture velocity area in front of the entrance. Detection rates among tag types were compared.

Results of the 2014 fish test in conjunction with the seasonal performance of the FS3001 transceiver installed at BCC indicate that the FS3001 transceiver is likely to meet the needs for a spillway PIT-tag detection system. The 2014 evaluation showed further increases in detection rates with additional modifications to the spillway transceiver. The 16-msec tag has outperformed the 32-msec tag in locations where electromagnetic noise levels reduce tag detections and in areas with high velocities reducing transit time within the detection field. Currently, we are investigating the best practical antenna configurations to provide complete coverage of an entire spillbay.

**HABITATS**

## Session 2: Ecosystem Science | Tues, April 5th | 11:10 am-12:43 pm

### Predator reintroduction alters species interactions and stability in a kelp forest ecosystem

Mark D. Scheuerell\*, Eric J. Ward, and Stephen L. Katz

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Global-scale losses of apex predators have led to profound changes in community structure and ecosystem processes, but the effects of predator reintroductions on recipient ecosystems remains poorly understood. We examined a long-term data set from a kelp forest in the California Channel Islands to characterize how species interactions and stability change over time following the reintroduction of sea otters, which had been extirpated from the island for more than 100 years. Rather than rely on ad hoc modifications to existing methods, we developed a novel time series model to estimate not only the strength and direction of interactions among species (e.g., competition, predation), but how those interactions change over time. We identified multiple interactions within the food web that changed coincident with the establishment of otters, including interactions consistent with the classic trophic cascade (effects of predators on grazers, and grazers on primary producers subsequent to otter establishment). By allowing species interactions to vary over time, we also found that stability decreased over time, which may have been initiated by fishing effects, but was ultimately sustained via increased otter numbers. Therefore, explicit consideration of the potential changes in the interactions among species following predator reintroduction, and their integrated effects on stability, may be more important than simply quantifying species abundance or diversity when evaluating the effectiveness of such conservation actions.

ECOSYSTEM SCIENCE

## Predator-prey interactions between harbor seals and migrating steelhead smolts revealed by acoustic telemetry

Barry A. Berejikian\*, Megan E. Moore, and Steven J. Jeffries

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Changes in the Puget Sound ecosystem over the past three decades include increases in harbor seal (*Phoca vitulina*) abundance and declines in a number of their preferred prey species. Steelhead trout (*Oncorhynchus mykiss*) smolts, which suffer high early marine mortality but are not known to be an important prey resource for harbor seals, were implanted with acoustic transmitters. Harbor seals were outfitted with acoustic telemetry receivers and GPS tags to investigate spatial and temporal overlap and evidence for predation by harbor seals on steelhead smolts. A total of 6,846 tag detections from 44 different steelhead trout smolts (from an initial group of 246 smolts released into two rivers) were recorded by the 11 recovered seal-mounted receivers. Central Puget Sound seal receivers detected a greater proportion of smolts surviving to the vicinity of the haul-out locations (29 of 51; 58%) than Admiralty Inlet seal receivers (7 of 50; 14%;  $P < 0.001$ ). Detection data suggest that none of the tagged smolts were consumed by the 11 monitored seals. Nine smolts were likely consumed by non-tagged harbor seals based partly on detections of stationary tags at the seal capture haul-outs, although we cannot exclude the possibility that some tags could have been deposited near the haul-outs by other predators. Smolts implanted with continuously pinging tags and smolts implanted with tags that were silent for the first 10 days after release were detected in similar proportions leaving Puget Sound (95% CI for the difference between proportions = -0.105 to 0.077) and stationary at harbor seal haul-outs (95% CI = -0.073 to 0.080). This study suggests that harbor seals contribute to mortality of migrating steelhead smolts, and we hypothesize that documented changes in the Puget Sound ecosystem over the past several decades may currently put steelhead smolts at greater risk of predation by harbor seals and possibly other predators.

### Abstract citation:

Berejikian B., Moore M., Jeffries S. 2016. Predator-prey interactions between harbor seals and migrating steelhead smolts revealed by acoustic telemetry. Doi 10.3354/meps11579.

ECOSYSTEM SCIENCE

## Distribution and community structure of pre-recruit groundfish and other taxa in the Northern California Current

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Fish early-life history stages may be sensitive indicators of environmental conditions and of future recruitment potential in adult fish stocks within the California Current ecosystem. Since 1983, NOAA's Southwest Fisheries Science Center (SWFSC) has conducted annual surveys to assess the distribution and abundance of young-of-year (YOY) groundfishes in the southern California Current (CC) to be used as pre-recruit indices for stock assessments. The present study is intended to expand the coverage of the SWFSC survey into the northern CC region using the same sampling protocol as the SWFSC. We collected pre-recruit groundfish (Pacific hake, flatfish, and rockfish) samples using a modified-Cobb midwater trawl fished at 4-6 stations along nine transects between 42.0-46.0°N latitude during June in 2011-2015 (although no sampling was conducted in 2012), and examined them for annual and spatial patterns of distribution and abundance. Overall species diversity was higher in 2015 than in any other sampled year and the community of taxa was significantly different than the other years. Flatfish comprised ~50% of the total groundfish catch, while rockfish and Pacific hake comprised ~25% each. Flatfish abundance increased continuously from 2001 to 2015, while rockfish increased from 2011 to 2013, before steadily declining through 2015. Pacific hake were relatively scarce in 2011-2014, but were found in high abundance mainly along the shelf break in 2015. Various latitudinal and cross-shelf distributional patterns were observed for the eight flatfish and ten rockfish species that dominated each taxon, respectively. Our results will be interpreted in the context of the entire coastwide survey during these years.

ECOSYSTEM SCIENCE

## FRAM's reproductive maturity program and its application for fisheries management

Melissa A. Head\*

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Since the initiation of the NWFSC's reproductive maturity program (FRAM Division) in 2009, we collected over 10,000 ovaries from 32 groundfish species. We identified several key factors essential for understanding reproductive biology of West Coast groundfishes: (1) spatial and temporal patterns, (2) oceanographic conditions related to skip spawning and abortive maturation, and (3) estimating biological (sexual) versus functional (potential spawner) maturity. FRAM is currently obtaining reproductive samples for multiple groundfish species via multiple sampling platforms, (West Coast groundfish trawl survey, Southern California hook and line survey, hake acoustics survey), observers (at sea hake observers), and collaboration with Washington and Oregon state departments (WDFW and ODFW). Samples are histologically assessed for maturity using a binocular microscope and imaging software. In the past many stock assessments relied on outdated or incomplete life-history information from opportunistic or geographically/temporally limited data sources. Our goal is to provide updated, coast wide maturity information on an annual basis to reduce uncertainty in parameters used to estimate spawning biomass and recruitment. Ecosystem variables, such as habitat, predator-prey interactions, food availability, upwelling, and oceanographic patterns may also have an outsized influence on the reproductive behavior of groundfish stocks in a given year. We are investigating how these variables affect skip-spawning and abortive maturation patterns and how spatial/temporal relationships are associated with maturity schedules.

ECOSYSTEM SCIENCE



## Community structure of eelgrass-associated invertebrates along the urban gradient of Puget Sound

Greg Williams\*, Shannon Hennessey, Jameal Samhour, Ole Shelton, Blake Feist, Adrian Stier, and Phil Levin

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The connection between humans and the sea is strong: estimates place over half of the world's population within 100 km of the coast, whereas within Puget Sound, WA 76% of the population lives along this coastal margin. While proximity yields numerous benefits to humans, it likewise impacts associated coastal systems due to a range of disturbances and altered watershed and shoreline processes. We sought to determine whether the cumulative effects of these activities along the land:sea interface in Puget Sound, WA were reflected in patterns of marine epibenthic invertebrate community structure and composition, specifically small crustacean (shrimps, crabs) and gastropod taxa with recognized ecological and commercial importance. Over three summers we sampled these organisms in shallow subtidal eelgrass beds near the mouths of 9 perennial streams flowing directly into Puget Sound, with watersheds spanning a gradient from highly rural (>80% forested) to heavily urbanized (>80% developed). In general, linear mixed effects models showed that herbivore biomass was characterized by a strong negative association to watershed imperviousness and a positive association with shoreline armoring. Carnivore biomass showed a similar directional, but lower magnitude, response to both of these factors, whereas omnivore biomass responded positively to both axes of urbanization. Among herbivores, Littorinid snail biomass was more strongly associated with armoring than that of any other family, whereas Caprellid amphipods represented the only exception to the typical herbivore pattern, suggesting urbanization may mediate some form of species replacement in these communities. This study suggests invertebrate community structure in more urbanized sites reflects patterns of intermediate disturbance and trophic downgrading, hypotheses that remain to be tested empirically using manipulative experiments that can better determine the proximate mechanisms for these patterns. Our findings also emphasize the value of examining functional as well as taxonomic responses, using continuous gradients of urbanization to interpret patterns.

ECOSYSTEM SCIENCE

## The effect of zooplankton behaviour on exposure to harmful pH conditions

Paul McElhany\*, Simone Alin, Vathsala DeSilva, Julie Keister, Tarang Khangaonkar, Tanika Ladd, Anna McLaskey, and Wen Long

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The vulnerability of a species to ocean acidification is a function of its sensitivity to carbonate chemistry conditions (e.g., pH) and the likelihood that it is exposed to deleterious carbonate chemistry conditions in the field. Understanding the likelihood of exposure requires integrating information on the spatial-temporal patterns of marine carbonate chemistry and the details of species' movement behaviour. The carbonate chemistry of the Salish Sea (NE Pacific) is highly variable, and the relative vulnerability of zooplankton species in this ecosystem may be strongly dependent on differences in their behaviour. We used an individually-based approach to simulate the movement of zooplankton through a circulation/water quality model of the Salish Sea. The high-resolution circulation model included carbonate chemistry parameters under both current conditions and anticipated future DIC loads. Zooplankton were modelled with a variety of different behaviours that correspond to behaviours observed in local species. Species that exhibit more surface-oriented behaviours experience relatively higher pH conditions than species undergoing daily vertical migrations, though this difference can be small relative to the influence of their location within the Salish Sea. The variability in carbonate chemistry condition exposure differed between species whose horizontal movement was current-driven and species with random direction swimming behaviour. A tendency to move toward or away from a non-carbonate environmental factor (e.g. temperature, oxygen, chlorophyll) affected likelihood of exposure to deleterious carbonate chemistry conditions. Species-specific movement behaviours can have a substantial influence on their vulnerability to ocean acidification by influencing species exposure to various carbon chemistry conditions.

ECOSYSTEM SCIENCE

## The inclusion of toxic exposures in a population model of Chinook salmon (*Oncorhynchus tshawytscha*) in the Willamette River basin

Jessica I. Lundin\*, Julann A. Spromberg, Jeff Jorgensen, Jim Myers, Paul Chittaro, Robert Neely, Rebecca Hoff, Troy Baker, and Nathaniel Scholz

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Salmon are a keystone species with a biological foundation that spans from coastal ecosystem health to human economies. Water pollution is becoming an increasingly important salmon conservation issue, particularly in watersheds affected by toxic runoff from urban development, industrial activities, and impervious surfaces such as roads. The physiological effects of many toxic substances are well studied, however the population-level effects are more challenging to evaluate due to differences in life history strategies. Toxic exposures are often not included in population abundance evaluations, particularly sub-lethal exposures or effects on prey abundance.

The purpose of this study is to quantify the impacts of toxic insults, such as mortality, sub-lethal changes in growth, behavior, and reproduction, and effects of prey abundance, on Chinook salmon (*Oncorhynchus tshawytscha*) in the Willamette River basin resulting from exposures to contaminants in Portland Harbor.

This study will build upon an existing population model of McKenzie River spring Chinook developed at the NWFSC, representing a sub-basin of the Willamette River. Known tissue residue concentrations from previous sampling efforts of juvenile Chinook at multiple sites throughout Portland Harbor will guide the assignment of chemical exposure. Toxicity will be determined by mechanism of action, and both mortality and sub-lethal effects dose-response relationships. Model scenarios will investigate the impact of toxic insults during smoltification and outmigration on overall population abundance and growth rate. Extrapolations of this model may be applied to Chinook salmon in other watersheds of the Willamette basin and used to guide recovery efforts. Lessons learned from this study will inform similar projects in the Puget Sound and elsewhere.

ECOSYSTEM SCIENCE

## Session 3: Seafood Safety/Species | Tues, April 5th | 2:30-3:53 pm

### The impacts of a massive harmful algal bloom along the U.S. west coast in 2015

Vera L. Trainer\*, Ryan McCabe, Barbara Hickey, and Raphael Kudela

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In 2015, a massive bloom of the marine diatom *Pseudo-nitzschia*, stretching from central California to northern British Columbia, resulted in significant impacts to coastal resources and marine life. This bloom was first detected in early May 2015, when Washington closed its scheduled razor clam digs on coastal beaches. It is the largest bloom in at least the past 15 years, and concentrations of domoic acid in seawater, some forage fish, and crab samples were the highest ever reported for this region. By mid-May, domoic acid concentrations in Monterey Bay, California, were 10 to 30 times the level that would be considered high for a normal *Pseudo-nitzschia* bloom. Impacts to coastal communities and marine life include razor clam and Dungeness crab closures in multiple states, impacting commercial, recreational and subsistence harvesters, anchovy and sardine fishery health advisories in some areas of California, and sea lion strandings in California, Oregon, and Washington. Other marine mammal and bird mortalities were reported in multiple states, with domoic acid poisoning the cause of impaired health or a strong contributing factor to compromised marine animal health. NOAA announced an Unusual Mortality Event for large whales in the western Gulf of Alaska, as the mortality of nearly 30 large whales has been recorded since May 2015. While the HAB is suspected of playing a role, there is no evidence yet that links these deaths to HAB toxins. Causes of the bloom's severity and coastwide distribution include *Pseudo-nitzschia's* resilience in the unusually warm, nutrient depleted Pacific Ocean water combined with perfectly timed storms, followed by the transition to spring upwelling conditions.

SEAFOOD SAFETY

## Intensive land-based farming of red and green macroalgae in the Pacific Northwest: an evaluation of seasonal growth and proximate composition

Bradley A. Gadberry\*, John Colt, Diane C. Boratyn, Desmond J. Maynard, and Ronald B. Johnson

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In the U.S., consumption of macroalgae is limited and occurs primarily in Hawaii and California. Most of this macroalgae is harvested from the wild. Regulatory restrictions, seasonal availability, and product quality issues limit increased use of wild macroalgae. Production of macroalgae from land-based cultivation systems can lower harvest costs, allow for precise control of rearing environments and product quality, and be used to capture nutrients from finfish aquaculture. In this study, we examined the seasonal growth and proximate composition of two species of red macroalgae (*Chondracanthus exasperatus*, and *Palmaria palmata*) and one species of green macroalgae (*Ulva rigida*), raised intensively in a land-based tank system. The water source for this study was from a land-based salmon rearing facility and tanks were additionally supplemented with nitrogen, phosphorous, and trace metals on a weekly basis.

The specific growth of all three species exhibited a similar pattern with the highest specific growth rate observed during summer months (*C. exasperatus* 7.8%, *U. rigida* 6.2% and *P. palmata* 8.2%). Growth of all three species was lowest around the winter solstice; however, senescence was only observed for *U. rigida*. There was a significant difference in protein content between the three species with the highest values found for *U. rigida* ( $29.5\% \pm 1.4\%$  on dry weight basis). Lipid content varied between species (0.95% to 2.78%) with the highest lipid observed for *U. rigida*, which additionally varied with season (0.58% to 4.82%).

SEAFOOD SAFETY

## Effects of dietary taurine and lipid on growth and nutrient utilization of juvenile sablefish *Anoplopoma fimbria* fed alternative plant based feeds

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Sablefish is a cold-water marine fish with good economic potential for aquaculture. Sablefish are valued for their high lipid content with flesh lipids typically exceeding 15 percent. Like other cold water marine species, feeds containing high levels of marine proteins are well utilized by sablefish, but are expensive and represent a potential barrier to the continued expansion of the aquaculture industry. The transition of sablefish to alternative, plant based feeds has the potential of reducing feed costs, but is problematic due to reduced palatability and the absence of essential nutrients, such as taurine, in terrestrial plants. In this multi-year study, we determined the dietary taurine requirement for juvenile sablefish. We additionally investigated whether there were interactive effects of dietary taurine and dietary lipid on nutrient utilization and whole body composition.

In the first year, juvenile sablefish were fed a plant based feed with graded levels of supplemental taurine to determine requirements for growth and feed efficiency. Using the five parameter, saturated kinetic model (5 SKM), peak weight gain was predicted at 1.5% dietary taurine. Optimum weight gain, as defined as at least 95% of peak response, was predicted between 0.4% and 5.8% dietary taurine. Peak feed efficiency was predicted at 1.1% dietary taurine with optimum feed efficiency predicted between 0.4% and 4.2%. Whole body taurine content increased asymptotically with increasing dietary taurine supplementation and became saturated at  $0.25 \pm 0.02\%$  taurine. In the second year, sablefish were fed low (10%) or high (20%) fat plant protein feeds, with or without supplemental taurine. As observed previously, dietary taurine had a significant effect on growth and nutrient utilization. Surprisingly, dietary lipid had no effect. Overall, results from this study show that taurine supplementation is beneficial for sablefish receiving plant based feeds, and that increasing dietary lipid does not diminish these benefits.

SEAFOOD SAFETY

## Impact of chiller failure on thermal shock in the incubation of sockeye salmon (*Oncorhynchus nerka*)

John Colt\* and Desmond Maynard

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In salmon recovery programs, chilled incubation water maybe required to match wild development rates. The most common failure mode for a chiller system is failure of the chiller or one of the recirculating pumps. Instantaneous temperature increases in direct-coupled chiller systems may result in abnormal development.

Three simulated chiller failures were monitored at the Burley Creek Research Station: primary chiller failure (Chiller Failure - CF), failure of the recirculating water pump (Pump Failure - PF), and chiller failure on a direct-coupled chiller (No Reservoir - NR). The largest temperature changes occurred in NR followed by PF and CF.

The temperature response for chiller and pump failures were modeled as two continuous-flow stirred-tanks reactor (CFSTR) in series:

$$T = T_i + (T_{\text{well}} - T_i) \left[ 1 - \frac{\tau_1}{\tau_1 - \tau_2} e^{-(t/\tau_1)} + \frac{\tau_2}{\tau_1 - \tau_2} e^{-(t/\tau_2)} \right]$$

Where  $\tau_1$ = volume of coldwater reservoir/system flow;  $\tau_2$ = volume of incubator/incubator flow, and  $t$  = time in minutes.

The temperature response of the no reservoir failure only depends on the incubator:

$$T = T_i + (T_{\text{well}} - T_i) \left[ 1 - e^{-(t/\tau_2)} \right]$$

The accuracy of the temperature response model was improved by using computed values for  $\tau_1$  and  $\tau_2$  rather than the theoretical values. Design must be based on temperature criteria, theoretical  $\tau_1$  and  $\tau_2$  values, and a safety factor for the volume of the coldwater reservoir because  $\tau_1$  and  $\tau_2$  are not known during design. Depending on the failure mode, this safety factor ranges from 1.15 to 1.25.

**SPECIES**

## Sexual growth dimorphism in sablefish

J. Adam Luckenbach\*, William T. Fairgrieve, Edward S. Hayman, and José M. Guzmán

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Sexual growth dimorphism (SGD) is a common natural phenomenon in which one sex outgrows the other. Numerous marine fishes exhibit SGD with females often growing faster and attaining a larger size than males. Fisheries data indicate that sablefish (*Anoplopoma fimbria*) is one such species; however no information is available on the precise timing, extent, or mechanism of SGD in sablefish. In fact, SGD is generally poorly understood but may be influenced by genetic factors and/or differences in age of puberty. Gaining a better understanding of SGD is important to both aquaculture and fisheries management. In an experiment initiated in 2011, we first documented the occurrence of SGD in a single family of captively reared sablefish. SGD occurred during the aquaculture “growout” period (i.e., before harvest size) and females were ~30% larger than males by 24 months after tagging. Based on these results a more comprehensive study was designed to identify the precise timing of SGD, how genetic background (family) influences SGD, and whether earlier male maturation may be the cause. Growth performance was assessed bimonthly in PIT-tagged sablefish from five different families reared together for 24 months. Fish were sampled bimonthly for an array of tissues including gonads, liver, muscle and blood. Initial results indicate that, regardless of sex, genetic background has a profound impact on growth. Moreover, SGD was observed in all five families of sablefish, with some variation in its timing and extent among families. Gonadal histology completed thus far suggests sexual maturation did not occur in either sex during the study, although gonad size (as indicated by gonadosomatic index) increased significantly. Analysis of other physiological and genetic samples is underway with the ultimate goal of revealing the basis of SGD.

**SPECIES**



## Arachidonic acid supplementation of brood diet affects nutritional composition and quality of eggs of serial spawning California Yellowtail, *Seriola lalandi*

Lisa Armbruster\*, Kevin Stuart, Mark Drawbridge, and Ron Johnson

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California Yellowtail (CYT) is a candidate aquaculture species for both recreational and commercial hatcheries. Eggs from cultured broodstock are currently of inconsistent quality and this variability limits production. Of the abiotic and biotic factors determining egg quality among teleosts, one important and customizable factor is broodstock nutrition. Marine finfish must obtain certain highly unsaturated fatty acids like arachidonic acid (ARA, 20:4 n-6) from their diet to support normal physiological functioning. This study supplemented a commercial diet with ARA for serial spawning CYT to evaluate if this fatty acid affects egg characteristics.

Captive-bred F1 CYT were maintained in experimental conditions under ambient water temperature and photoperiod at Hubbs Sea World Research Institute in San Diego. Three months prior to the spawning season, fish were transitioned to the ARA supplemented or a control diet.

Fish volitionally spawned 53 times in the control treatment and 30 times in the ARA treatment. Of these, a higher percent of ARA spawns (30%) consisted of greater than 70% floating eggs than the control (7.5%).

Egg nutrient composition was significantly affected by diet. The ARA treatment yielded eggs with 1.46% lipid, slightly less than the 1.51% lipid of control eggs ( $p=0.0458$ ). Fatty acid analysis of extracted lipids confirmed the ARA supplemented diet had 4.7% ARA while the control diet had significantly less at 1.4%. Importantly, the supplemental ARA induced a very significant two-fold increase in ARA content of eggs at 4.8% versus 1.9% in the control. This difference contributes to a significantly lower ratio of eicosapentanoic acid to arachidonic acid in eggs of the ARA supplemented fish. It is anticipated this altered ratio will affect synthesis of 2 and 3 series prostanoids by the developing fish embryo, which will ultimately affect survival. Further studies are planned to assess the long term effects of this dietary change.

SEAFOOD SAFETY

## Session 4: Ecosystem Science | Wed, April 6th | 9:05-10:30 am

### Determining the vulnerability of coastal communities to social and ecological change

Jameal Samhouri\*, Emma Fuller, and Karma Norman

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Coastal communities reliant upon fisheries are perhaps the most closely connected to the dynamic and changing oceans. However, determining how these communities are likely to be influenced by changes in marine ecosystems remains a challenge. In this talk we explore approaches for estimating the vulnerability of fishermen, and the coastal communities in which they live, to climate-induced ecological changes and to changes in management. We focused our analysis on the U.S. California Current ecosystem, considering the vulnerability of communities of fishermen, specifically, based on patterns of fisheries participation. To do so, we used trips, landings, and revenue data to determine each vessel's fishing strategy—the fisheries in which it participated—and developed networks to visualize how the vessels in each coastal community were connected via shared fishing strategies. We evaluated the consequences of two different shocks to the participation networks: (i) a Harmful Algal Bloom that caused the Dungeness crab fishery to close, and (ii) the implementation of catch shares-based management for groundfish trawlers. These network simulations predicted how fisheries participation may be redistributed in the face of social and ecological shocks, and we interpreted them in the context of a commercial fishing reliance index developed previously for U.S. West Coast communities.

ECOSYSTEM SCIENCE

## Assessing sociocultural vulnerabilities of ocean acidification, a community-based project with the Squaxin Island Tribe

Melissa Poe\*, Jamie Donatuto, Charlene Krise, and Phil Levin

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This presentation discusses the sociocultural dimensions of ocean acidification (OA) through a community-based participatory project with the Squaxin Island Tribe located in South Puget Sound. Ecological conditions in Puget Sound are complex, and face increasing pressures and uncertainties from climate-related ocean changes. One type of ocean change, OA, is altering bio-chemical processes of coastal waters, with potentially negative impacts to marine resources important to human communities. For many millennia, the people of the Squaxin Island Tribe have relied on marine resources such as clams, oysters, and salmon for food, ceremony, and trade. Rights to access and use these important seafoods are protected in the 1854 Treaty of Medicine Creek. Since 2014, our team has conducted interviews and community-based participatory scenarios workshops to: document the social, cultural, and health importance of shellfish; to identify cultural and community vulnerabilities to OA; and to use results to help prioritize action and adaptation.

ECOSYSTEM SCIENCE

## The effects of catch share management on safety and risk taking in the Pacific Northwest fisheries

Lisa Pfeiffer\*

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Fishing is the most dangerous job in the United States. When fisheries management creates the incentive to “race for fish”, a fishing season can be reduced to only a few days and involve around-the-clock fishing in life-threatening weather conditions. Overloaded vessels, ignoring maintenance problems on vessels, and fishing in dangerous conditions may be commonplace. However, catch share management can reduce the incentive to race for fish, and one of the many results of catch share management has been a significant decrease in the speed and intensity of fishing and a lengthening of the fishing season. This is expected to increase safety in fisheries. We evaluate the effect of the transition from limited entry to catch share management on risk-taking behavior in two important Pacific Northwest fisheries, the fixed gear sablefish fishery and the groundfish trawl fishery. The two fisheries had very different management institutions prior to their respective catch shares program. The fixed gear fishery had “derby” fishery characteristics, while the trawl fishery was managed with trip limits and area closures but was open year-round. The probability of fishing in poor weather conditions (spatially averaged maximum daily wind proxies weather conditions) is modeled conditional on expected profits, and describes a captain’s propensity for risk taking. We find average maximum wind speed had a negative effect on the probability of going fishing in all management regimes, but is larger under catch shares for both fisheries. However, the effect was much larger in the case of the derby fishery.

ECOSYSTEM SCIENCE

## The economics and social science of crew in the West Coast groundfish catch share program

Erin Steiner\* and Suzanne Russell

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Catch share programs can have far-reaching effects on coastal communities, ecosystems, and fishery participants. Crew are an integral component of any fishery; however, the ability to analyze how management actions affect crew are often limited due to data availability. We use two unique data sets, a mandatory cost earnings data collection of all U.S. West Coast Trawl Groundfish catch share program vessels as well as a voluntary social science study of participants, to look at how crew have fared during the first four years of the program. The West Coast fishery did not operate as a derby in the years prior to the catch share program and so the resulting changes to crew differ from other catch share programs. We find an increase in both the daily wage per crew member as well as an increase in the total annual wages earned while participating in the catch share program.

ECOSYSTEM SCIENCE

## West Coast Groundfish Catch Share Program: Economic overview of the at-sea sector

Amanda Warlick\* Erin Steiner, Marie Guldin, and Lisa Pfeiffer

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The U.S. West Coast groundfish trawl fishery takes place off the coasts of Washington, Oregon and California, and is managed by a catch share program consisting of cooperates and individual fishing quota for catcher vessels, motherships, catcher-processors, first receivers, and shorebased processors. To monitor the economic effects of the transition to catch shares, the Economic Data Collection Program has collected information on costs, revenues, and other operational characteristics for all fishery participants since 2011, including baseline information from 2009 and 2010, allowing the comparison of pre- and post-catch share data. In 2014, the most recent year of data, catcher-processors spent an average of 59 days operating on the West Coast, earning approximately \$11 million in revenue and spending \$5.5 million in costs. Similarly, mothership vessels earned almost \$11 million in revenue and spent \$8.5 million in costs, leading to an average net revenue of almost \$2.5 million per vessel. These data are collected and compiled in such a way as to allow analysis of economic performance according to a number of variables, including vessel size, target species, gear type, and home port, or to allow the calculation of daily and production-based rates, thus providing invaluable insight for fishery managers. Compiling, analyzing, and communicating these data are critical to determining whether the catch share program is meeting the goals set forth by the Pacific Fishery Management Council, particularly as the timeline for formal review under the MSA approaches.

ECOSYSTEM SCIENCE

## Processor-allocated quota in IFQ programs – An analysis of the shoreside Pacific whiting fishery

Marie Guldin\*

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Much of the literature in fisheries economics focuses on the harvesting sector. Due to lack of data, a less explored area is how the fish processing sector is affected by fishery management strategies. Several individual fishing quota programs thus far have granted property rights to fish processors in an effort to address potential loss in processor rents. One such program, the West Coast Groundfish Trawl Catch Share Program, allocated 20% of the Pacific whiting harvesting quota to the processing sector. I combine a dataset of quota transactions in the Pacific whiting fishery with fish ticket data to examine how processors utilize their harvesting quota allocation. Tracing quota transfers from the processing sector to the harvesting sector reveals processors give quota at differing rates to vessels that deliver Pacific whiting to them, rather than price quota directly. In this presentation, I will share preliminary research assessing what market conditions would likely yield such an outcome in order to provide a better understanding of how processor-allocated quota could impact fisheries.

ECOSYSTEM SCIENCE

## Discard trends in a rationalized fishery

Kayleigh A. Somers\*, Jason E. Jannot, Yong-Woo Lee, and Jon T. McVeigh

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In 2011, Individual Fishing Quotas (IFQs; a catch share program) were introduced to the U.S. west coast bottom trawl fishery. IFQs create individual accountability for discards, improving economic stability for fishermen and long-term sustainability for fish stocks. Catch share programs should incentivize ecologically sustainable fishing practices, such as reducing discard of overfished stocks. The few studies examining the ecological sustainability of IFQ programs focus mainly on target and overfished stocks and ignore species outside of the formal IFQ framework.

We used data from the West Coast Groundfish Observer Program (WCGOP) to explore how these trends differ between species explicitly managed by IFQs, species managed by the Fishery Management Plan (FMP), and species caught but not managed within the FMP. Specifically, we asked how trends for these groupings differed in terms of discards, landings, discard rates, and catch proportion retained before and during IFQ management.

For all species grouped together, total discard and rates of discard to targeted catch decreased with IFQs. Discards of FMP-managed species decreased by the greatest weight, while non-FMP species decreased by the greatest percentage. Discard rates decreased across each grouping, but the percentage decrease in IFQ species was lower than other groupings.

The proportion of catch retained did not change for the non-FMP species grouping, remaining around 4%. The proportion of groundfish species retained increased from a minimum of 58% prior to IFQ management to a mean of greater than 90% in years with IFQs. The IFQ species grouping showed an even greater increase in retention percentage, from a minimum of 14% retained prior to IFQ management to 93% retained in 2014.

These preliminary results show that changes in discard behavior differ greatly between species groupings, the implications of which should be considered when assessing the sustainability of IFQs.

**ECOSYSTEM SCIENCE**

## Session 5: Ecosystem Science/Species I Wed, April 6th I 11:00-12:30 pm

### A genetic inventory of marine organisms of the Salish Sea

Gary A. Winans\* and Jon Baker

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To monitor and manage for the health of the Salish Sea marine ecosystem, we need to include information on the population structure for a diverse array of marine organisms. Data for population structure, i.e., the amount and pattern of genetic differentiation, provide a framework to evaluate the evolutionary potential of species, the spatial scale of local adaptation, and the potential for broad or narrow geographic response of species and communities to environmental change or disasters. Because many marine organisms have a pelagic larval stage, it is presumed tacitly that each species consists of one panmictic population and therefore evolves and can be managed as one unit. However preliminary studies of genetic variability of as diverse group of animals such as Dungeness crabs, Pacific herring, harbor seals, and red sea urchins in the Salish Sea indicate that genetic homogeneity among populations is not the case. We summarize available genetic information for marine plants and animals in the Salish Sea, synthesize general patterns of variability over taxa and habitats/food webs, and highlight data gaps. We argue that to understand marine ecosystem functionality and to monitor and conserve its constituent species and species populations more studies of biodiversity are still required.

ECOSYSTEM SCIENCE

### Towards quantitative multi-species environmental DNA surveys

James L. O'Donnell\*, Ryan P. Kelly, Natalie C. Lowell, Andrew O. Shelton, Jameal F. Samhour, Shannon M. Hennessey, Blake E. Feist, and Gregory D. Williams

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Recent advances in molecular tools have made it possible to survey organisms by simply sampling from the environment they occupy. This approach has the potential to make substantial advances in widespread applications, from stock identification and quantification to habitat use by protected species. However, the quantitative limits of this approach are not yet clear. For example, what is the minimum number of individuals of a given species that can be detected? I will explore the promises and practical limitations of environmental DNA (eDNA) surveys in marine systems through the lens of completed, ongoing, and proposed studies. These include community surveys of kelp forest and eelgrass habitats, method development for increased reliability, and statistical approaches to improving quantitative estimates. In our nearshore marine field studies, we found that surveys using environmental DNA detected a much broader suite of taxa than traditional visual surveys. These results confirm that eDNA is an effective survey tool for marine environments, and indicate that with proper investment, there is promise for quantitative estimates of biomass from environmental samples.

ECOSYSTEM SCIENCE

## Genomic signatures of migration in *Oncorhynchus nerka* to inform conservation and management of endangered stocks

Krista M. Nichols\*, Christine C. Kozfkay, and Shawn R. Narum

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Conservation of life history variation is an important consideration for many species with trade-offs in migratory characteristics. Many salmonid species exhibit both resident and migratory strategies that capitalize on benefits in freshwater and marine environments. In this study, we investigated genomic signatures for migratory life history in collections of resident and anadromous *Oncorhynchus nerka* (kokanee and sockeye salmon, respectively) from two lake systems, using ~2,600 SNPs from restriction-site associated DNA sequencing (RAD-seq). Differing demographic histories were evident in the two systems where one pair was significantly differentiated (Redfish Lake,  $F_{ST} = 0.091$  (95% confidence interval: 0.087 to 0.095)) but the other pair was not (Alturas Lake,  $F_{ST} = -0.007$  (-0.008 to -0.006)). The lack of differentiation between Alturas Lake kokanee and anadromous sockeye suggests that the resident kokanee population produces small numbers of migratory individuals. Outlier and association analyses identified several candidate markers in each population pair, but there was limited evidence for parallel signatures of genomic variation associated with migration. Despite lack of evidence for consistent markers associated with migratory life history in this species, candidate markers were mapped to functional genes and provide evidence for adaptive genetic variation within each lake system. Life history variation has been maintained in these nearly extirpated populations of *O. nerka* and conservation efforts to preserve this diversity is important for long-term resiliency of this species.

SPECIES



## Cooperative research sheds light on the status of ESA-listed rockfish in Puget Sound

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Yelloweye *Sebastes ruberrimus* and canary *Sebastes pinniger* rockfish populations in Puget Sound, WA were listed as “threatened”, while bocaccio *Sebastes paucispinis* were listed as “endangered” under the U.S. Endangered Species Act in 2010. However, considerable uncertainty characterizes the designation of these populations as “distinct population segments” (DPS) due to limited genetic and demographic information. This project’s goals were to collect new biological and genetic information to determine whether ESA-listed Puget Sound rockfish are genetically similar to or distinct from their respective coastal populations and to create working relationships with the recreational fishing community. In 2014 and 2015, we worked with local recreational charter boat captains and anglers to collect fin clips from yelloweye, canary and bocaccio rockfish inside the Puget Sound DPS and the Strait of Juan de Fuca. We also received fin clips from each species from the outer coast of Washington and Oregon and yelloweye from coastal and inland waters of British Columbia. All fin clips were prepared and analyzed using restriction-site associated (RAD) DNA sequencing. Results show that canary rockfish in Puget Sound are genetically similar to canary rockfish on the outer coast, suggesting that canary rockfish in Puget Sound are not a distinct population segment from the outer coast. Yelloweye rockfish showed distinct genetic differentiation between individuals from Puget Sound and the outer coast. Individuals from inland waters of British Columbia were genetically similar to Puget Sound individuals. Yelloweye rockfish in Hood Canal, WA were identified as a third genetic cluster. These results will have immediate and direct implications for the ESA-listing status of canary rockfish and the boundaries of the DPS for yelloweye rockfish. Moreover, this work has developed a strong working relationship between NMFS and the local recreational fishing community that can only help with the management of these species in the future.

**SPECIES**

## The secret life of crabs: movement and behavior of Dungeness crab as determined by benthic video imaging and acoustic telemetry

Curtis Roegner\*

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The Columbia River estuary and the adjacent nearshore zone are important habitat for Dungeness crab (*Cancer magister*), and these areas support valuable commercial and recreational fisheries. The estuary sustains high densities of juvenile crabs and is thought to function as a nursery, while larger crabs and especially females are believed to migrate to more saline nearshore habitat to mate and release brooded larvae. However, little is known about these crab migrations or indeed crab distributions or movements between habitats in general. One possible impact on crab populations is dredge operations in the mouth of the Columbia and sediment deposition events designed to aid beach nourishment. To learn more about crab movements and the effects of dredge depositions, we have been using acoustic telemetry and benthic video imagery to track crabs during deposition events. This talk will present video and animation of recent experiments in the nearshore zone.

SPECIES

## Improvements to survival estimation for migrating juvenile salmon using capture-recapture models with adaptive nonparametric smoothing

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The seaward migration of juvenile salmon is an important part of their life history and the survival of listed stocks during their migration through dams and reservoirs in the Columbia Basin is intensely monitored. Standard capture-recapture methods currently used to estimate survival for these stocks do not fully account for time-varying detection probabilities and do not properly account for time-dependent covariates. We propose a fully Bayesian method for modeling survival which uses a novel nonparametric smoothing approach to estimate nonlinear dynamic trends in detection and survival probabilities within a Cormack-Jolly-Seber capture-recapture modeling framework, and uses data augmentation to account for missing time-dependent data. This formulation allows adaptation to local changes in smoothness of an unknown function, including abrupt changes or jumps, which provides the flexibility to model complex temporal trends in the absence of detailed structural models or extensive covariate data. This flexibility results in reduced bias and increased precision of estimated survival and detection probabilities. We apply this method to estimating survival of migrating juvenile salmon in the Snake River and compare results to those from other estimation methods.

SPECIES

### Using satellite-tag locations to improve acoustic detection data for endangered killer whales: a case study to better identify potential critical habitat in a U.S. Navy training range

M. Bradley Hanson\*, Eric J. Ward, Candice K. Emmons, Marla M. Holt, and Damon M. Holzer, Marc O. Lammers, Gregory S. Schorr, and Russell D. Andrews.

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Using acoustic detections of cetaceans to assess habitat use, and quantify anthropogenic impacts to populations has increased rapidly as a research and management tool. In some cases, large arrays (up to several hundreds) of acoustic recorders have been deployed, but in other cases, acoustic data is much more limited in space or time. Providing better estimates of season-to-season or year-to-year variation in species occurrence will help inform future management actions, such as the extent of Critical Habitat designated under the US Endangered Species Act, particularly when the area potentially overlaps with a US Navy training range. In this analysis, we integrate limited acoustic detections of endangered southern resident killer whales from the coastal waters of Washington in winter and spring over a 7-year period with three other data sources: opportunistic visual sightings, proportion of time vocalizing as determined with a towed hydrophone array when the whales were in visual contact in this area, and output from a state-space movement model fit to the locations from a single satellite-tagged individual in this region. When acoustic or any other dataset is limited by sample size, the advantage of integrating multiple data sources is improved precision of predictions. In this case, estimated rates of travel from the movement model have the effect of constraining the possible movements inferred from the acoustic detections alone. Even if the placement of acoustic detection devices is designed to maximize detections, analyses of these types of data for animals with large ranges, and/or move rapidly, may be limited if sample sizes are small. Integrating other data sources – particularly in a Bayesian framework that allows for the inclusion of prior information – allows for estimates of detection probabilities, and improved estimates of habitat use.

**SPECIES**

## Vessel noise exposed to Southern Resident killer whales: a comparison before and after U.S. vessel regulations

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Disturbance from vessels and noise is a key threat to the recovery of the Southern Resident killer whale population. In the U.S., vessel regulations were developed to protect these endangered killer whales from such disturbance, particularly given the extent of whale-watching activities in core summer habitat. Under current federal regulations, most vessels are prohibited from approaching within 200 yd and intercepting the path within 400 yd of any killer whale in the inland waters of Washington State. Voluntary vessel guidelines currently exist in Canada. We measured noise levels from suction cup-attached acoustic recording tags attached to Southern Resident killer whales before and after regulations went into effect. During tag deployments, we also collected detailed geo-referenced vessel data relative to the tagged whale to relate to measured noise. We expected to see a reduction in noise exposure after regulations given the increased vessel viewing distance in the U.S. (and because sound loses strength as it propagates away from the source). Received noise levels ( $\text{dB}_{\text{rms}}$  re  $1\mu\text{Pa}$ , 1-40 kHz band) were significantly different across years but, unexpectedly, the highest noise levels occurred in a year after vessel regulations went into effect. Five fixed and several random factors were incorporated as predictors of observed noise in a linear mixed-model analysis using AIC selection. Of the fixed factors considered in the analysis, year, vessel count and vessel speed best explained differences in received noise levels. Surprisingly, country and vessel distance were not included in the best model. Unintended changes in whale-watching vessel practices after regulations went into effect likely explain these findings. The results, along with those of other related studies, provide the needed data to aid in the evaluation of the effectiveness of current vessel regulations and inform potential future revisions.

SPECIES

## Impacts of pinniped predation on Columbia River Chinook salmon populations

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Predation on adult salmon by pinnipeds (California sea lions, Stellar sea lions, and harbor seals) is an increasing problem in the Columbia River Basin. The abundance of California sea lions hauling out in Astoria, Oregon, which is near the mouth of the Columbia River, has increased by eight-fold over the past four years. Early-arriving salmon are most susceptible to predation, because sea lions depart the Columbia River estuary by early June. Consequently, we evaluated daily survival rates of adult Chinook salmon from Astoria to Bonneville Dam, based on a mark-recapture study conducted in 2010–2014. Daily survival rates were converted to average population-specific survival rates, which were integrated into life-cycle models to evaluate the impacts of pinniped predation on population viability. Survival rates were modeled as a function of year and date passing Astoria, with logistic regression. Our preliminary models suggest that survival rates of natural origin fish were low at the beginning of the run in late May (30–70%), and increased as the run progressed (80–100% in May–June). Overall, survival was considerably higher in 2010–2012 than 2013–2014, consistent with counts of sea lions in Astoria. We weighted daily survival rates by population-specific run-timing distributions to estimate average population-specific survival rates. In the higher-survival years (2010–2012), average survival ranged 84–95% across populations, varying as a function of population-specific run timing. Average survival ranged 59–87% across populations in the lower-survival year (2013–2014). We added a 20% mortality rate for returning adults into a life-cycle model of natural-origin Wenatchee River spring Chinook salmon, based on our estimates of survival rates in 2013–2014. The probability of a quasi-extinction event occurring in the next 100 years increased from <5% to >15%. Impacts are expected to be greater for earlier-arriving populations.

**SPECIES**

## MARSS models for estimating population status for data-poor species: three ESA listed rockfishes in Puget Sound

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Time-series analysis is a fundamental tool for evaluating the status of species thought to be potentially at risk of extinction. We show how multivariate autoregressive state-space models (MARSS) can combine gappy data from disparate gear types and multiple survey areas to estimate the regional population trajectory over time, the population growth rate, and the uncertainty in these estimates. MARSS can also test hypotheses about the spatial structure of subpopulations.

We illustrate our approach with an analysis of population status for three, rockfishes listed in Puget Sound WA under the Endangered Species Act: bocaccio (endangered), yelloweye (threatened) and canary rockfishes (threatened). Data were available from three sources: 1) Washington Department of Fish and Wildlife (WDFW) recreational fishery survey, 2) REEF scuba surveys, and a WDFW trawl survey. The surveys use different gear and sample different depths likely providing information on different rockfish assemblages. Changes in bag limits reduced catch by recreational fishers through time, and all three data sets have data gaps. Because there were few observations of the listed species, we estimate the population trajectory and growth for 'total rockfish'. We then make inferences about the listed species by evaluating evidence that they have increased or decreased as a proportion of the assemblage. Our analysis indicates that total rockfish declined  $\sim 3.1 - 3.8\%$  per year from 1977-2014 with similar rates of decline north and south of Admiralty Inlet. The listed species all declined as a proportion of the local assemblage suggesting stronger rates of negative population growth for the listed species than for total rockfish. Although rates of decline were similar in north and south of Admiralty Inlet, there was evidence of temporal independence in these two regions as evidenced by higher and more variable catch north of Admiralty Inlet and data support for unique trajectories (year to year abundances).

SPECIES

## Potential impacts of Cowcod Conservation Areas on shelf rockfish in the Southern California Bight

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We annually conduct a fishery-independent hook and line survey to monitor groundfish associated with hard bottom habitats within the Southern California Bight. The survey was developed in 2003 and is a collaborative effort among Pacific States Marine Fisheries Commission (PSMFC), Northwest Fisheries Science Center (NWFSC), and southern California's sportfishing industry. The survey's historical sampling frame (2003-2013) consisted of 121 fixed sites and excluded two large Cowcod Conservation Areas (CCAs). The CCAs were implemented in 2001 to protect shelf habitat and fishery resources in areas where cowcod (*Sebastes levis*) are most abundant. Bottom-fishing at depths greater than 20 fathoms is mostly prohibited within the CCAs. In 2014, at the request of the Pacific Fishery Management Council, the hook and line survey initiated sampling at 42 sites within the CCAs and added another 34 new sites in 2015. Preliminary results for recreational and commercially important species suggest larger observed mean sizes of vermilion rockfish (*S. miniatus*) and cowcod inside the CCAs versus outside, but no difference in size for bocaccio (*S. paucispinis*). Vermilion rockfish composed a higher proportion of survey catch outside the CCAs than inside, while the proportions of cowcod and bocaccio catches were not significantly different. With only two years of data within the CCAs, the hook and line survey will continue to monitor these sites into the future and document other potential impacts on shelf rockfish related to the CCAs. In addition, sampling in the CCAs should allow for a more robust estimation of relative abundance for several important rockfish species.

SPECIES

## The 2016 winter hake survey – watching hake when they think no one is watching

Sandy Parker-Stetter\*, Aaron Chappell, Allen Shimada, Anthony Odell, Ben Simpson, Carlos Godínez-Pérez, Cassandra Donovan, Dezhang Chu, Doug Draper, Jenni Hood, Kayleigh Somers, Michael Gallagher, Nick Tolimieri, Pete Frey, Rebecca Thomas, Steve de Blois, Tom Holland, and Victor Simon (alphabetical by first name)

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Despite the economic and ecological importance of Pacific hake (*Merluccius productus*), little is known about what they do during the winter or where they go. Information on Pacific hake biomass and biology, for use in the stock assessment, has historically been collected during the summer (June-September) by the FRAM-FEAT team jointly with the Department of Fisheries and Oceans Canada. During this time, hake are in their summer feeding distribution between southern California and British Columbia or Alaska. In contrast, many migratory species around the world are surveyed while they are aggregated in a concentrated area during spawning. Because these surveys cover a comparatively smaller area, they can reduce ship and personnel costs and potentially provide a more accurate estimate of abundance. For Pacific hake, spawning occurs during the winter. With a complement of (deranged and) unruly scientists, the 2016 Winter Hake Survey was conducted aboard the NOAA Ship *Bell M. Shimada* between Newport, OR and San Diego, CA from January 9 to February 9, 2016. The formal goals of this survey were to characterize the distribution of spawning hake, spawning hake aggregations, and the fish within those aggregations, in order to evaluate the feasibility of, and inform the design of, a potential future winter spawning hake biomass survey. Informally, this survey also provided key information on hake biology and distribution for comparison with existing hypotheses and historical observations. This presentation will provide an overview of what was planned for the 2016 Winter Hake Survey, what was actually done, challenges, and initial perspectives/findings from the at-sea science party.

**SPECIES**



## Steelhead in a changing climate: trophic dynamics and growth response to temperature among 3 Hood Canal rivers, Washington

Katy Doctor-Shelby\* and Barry Berejikian

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Due to the predicted effects of climate change on freshwater streams and the recent ESA listing of Puget Sound *Oncorhynchus mykiss* (steelhead), it is increasingly important to understand the mechanisms that mediate freshwater growth of Puget Sound steelhead. Our study examined whether seasonal and age-specific growth of juvenile *O. mykiss* varied among 3 rivers of the Hood Canal region, Washington, each with a unique thermal and hydrologic regime. Further, we identified summer low-flow patterns of prey availability and diet contents of age-1 and age-2 *O. mykiss* in each river and determined that these, along with seasonal thermal patterns affected consumption rates, growth and growth efficiency using a bioenergetics modelling approach. Our study revealed that prey availability and fish diet varied among rivers, but not between age-1 and age-2 *O. mykiss*. Seasonal consumption rates ranged from 17%-27% of maximum consumption and summer rates were lower than or equal to winter rates in all rivers. Model-derived growth efficiency and growth rates were higher in the summer months for the transitional, colder Duckabush and SF Skokomish rivers. Opposite patterns were observed in the warmer, rain dominated Dewatto river where growth was higher in the winter months. Given each river's estimated consumption rate, the simulated growth responses for the Dewatto age-1 fish in both April and September resulted in lower optimal growth rates than either the SF Skokomish or the Duckabush Rivers. Expected growth responses to temperature indicated that optimal growth and thermal tolerance differed among populations, seasons and for fish of different size. Our study revealed both feeding rate and temperature limit the growth of juvenile *O. mykiss* in these Hood Canal rivers and due to differing seasonal patterns of growth among these rivers, climatic shifts to warmer stream temperatures and altered flow regimes may affect trophic structures within each river differently.

SPECIES

## FRAM Data Warehouse

Seyed “Mak” Ahmad, Todd Hay\*, Beth Horness, Will Smith, Darla Truitt, and Brandon Van Vaerenbergh

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The Fishery Resource Analysis & Monitoring (FRAM) division performs a variety of data collection including three fishery independent surveys (trawl, hook & line, and acoustics), economic and social science surveys, habitat surveys, and commercial fishing bycatch data collection. The amount of data collected is significant, for instance the trawl survey alone collects nearly a quarter of a billion sensor data readings annually. The FRAM data team has recently build a data warehouse for storing and provisioning this data for internal and external users. This data warehouse resides in a robust open source technology stack leveraging Postgresql / Enterprise Database for the data warehouse, python for the application programming interface (API) / middle tier, and AngularJS, cesiumjs, dataTables, and d3js for the web application user interface. Prototype R and Microsoft Excel applications have also been built that leverage the API. Multiple FRAM datasets have already been transformed and loaded into the data warehouse, with more being added all the time with a goal of containing a complete set of FRAM data. During this talk, we will discuss the capabilities of the warehouse to include the available data sets and functional capabilities of the system, provide a schedule for future enhancements and data set incorporation, provide a live demonstration of the capability, and seek audience/potential user feedback on desired enhancements.

**SPECIES**

# **5** Northwest Fisheries Science Center **TH SCIENCE SYMPOSIUM**

Fisheries for the Future | April 5-6, 2016



# Poster Abstracts

### Patterns in restoration placement and tools to help prioritize restoration planning for ESA listed salmonids

Katie Barnas\* and Monica Diaz

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In the Pacific Northwest of the United States, hundreds of millions of dollars (\$US) per year are spent on thousands of restoration projects across the extent of ESA listed Pacific Salmon — often without clearly connecting restoration actions to ecosystem and salmon population needs. Numerous entities select and fund projects based on agency/organization needs or availability of funds with little centralized planning nor post-project monitoring. The need therefore arises to (1) understand patterns in restoration placement and for (2) metric development to identify whether ecosystem and species level restoration needs are being met by the accumulation of implemented projects. We compared restoration location to Intrinsic Potential and habitat disturbance, and looked at restoration type and cost frequencies to describe patterns in project and location choice. We also reviewed recovery plans to identify ecological needs and compared these to the distribution of co-located restoration projects. We developed two metrics to help guide future restoration planning; one describes the unit scale match/mismatch between projects and ecological concerns, the other correlates ecological need with need treated by projects across units. We found to date, populations with more identified ecological concerns contained more restoration effort, but the frequency of ecological concerns in recovery plans did not correlate with their frequency as restoration targets. Instead, restoration projects were strongly biased towards less expensive types. Many ESA listed salmon populations had a good match between need and actions noted in their recovery plan. All analyses show there is still considerable room for gains in restoration funding and placement which can be aided by the incorporation of these new metrics into project funding decisions.

HABITATS  
P-1

## Persistent Organic Pollutants in Female Humpback Whales from the Gulf of Maine

Keri Baugh\*, Bernadita Anulacion, Jooke Robbins, Gina Ylitalo

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Blubber biopsy samples from female humpback whales in the Gulf of Maine collected between 2004 and 2012 were analyzed for Persistent Organic Pollutants (POPs) including polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethanes (DDTs), chlordanes (CHLDs), polybrominated biphenyl ethers (PBDEs) and hexachlorocyclohexanes (HCHs). Samples were collected from 38 females that included a range of age classes (eg. adult, subadult, juvenile, calf), and when it was possible to determine, reproductive status (eg. nursing, pregnant, lactating) of the animal was recorded. Gas chromatography with mass spectrometry (GC/MS) was used to measure the POPs and the concentrations of these lipophilic contaminants were then normalized to the percent lipid of the sample. As with other cetaceans, concentrations of POPs in baleen whales are often higher in the calves and juveniles than the adult females due to maternal offloading. To determine if contaminants were transferred from mother to calf, statistical tests were performed on the sum concentrations of the classes of POPs measured and the different age classes. Understanding the pollutant burden in female humpback whales and characterizing the transfer of these pollutants from mother to calf is important in evaluating this as a potential risk to the health of this population.

SPECIES  
P-2

## Feeding ecology of select groundfish species captured in the Northwest Fisheries Science Center's West Coast Bottom Trawl Survey, using gut contents and stable isotopes

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We are examining the diets of multiple groundfish species as an ongoing component of the NMFS West Coast Bottom Trawl Survey. Stomachs and tissue samples were collected at sea and preserved for gut content and stable-isotope analyses. We focused on several species of *Sebastes* and now have stomach content and stable-isotope data covering multiple years. Yellowtail, darkblotched, canary, sharpchin and stripetail rockfishes prey largely on zooplankton, with euphausiids composing a majority of their diet. Shrimp also contribute significantly to the diets of darkblotched and canary rockfishes, whereas bocaccio, yelloweye and chilipepper rockfishes all share a highly piscivorous diet. Greenstriped and rosethorn rockfishes show a strong preference for benthic prey, greenstriped preferring various shrimp species, and rosethorn preferring a mix of shrimp and galatheid crabs. Finally, widow rockfish and Pacific ocean perch exhibit a more omnivorous feeding strategy, eating a variety of zooplankton, including euphausiids, amphipods, shrimp and gelatinous organisms. Stable-isotope values averaged by year indicate that bocaccio and yelloweye rockfish feed approximately one trophic level above Pacific ocean perch and above darkblotched, greenstriped, sharpchin, stripetail and widow rockfishes. All other species in this study feed at mixed trophic levels. Multivariate analyses of diet data show significant differences in diet among species but strong overlap among benthic and bentho-pelagic species. Stable-isotope data also show significant differences among species and years. These results demonstrate the groundfishes in this study are significant consumers in both benthic and pelagic habitats, feeding across multiple trophic levels.

ECOSYSTEM SCIENCE  
P-3

## Avian community response to salmon recolonization in the Cedar River Watershed, WA

Hannah Clipp\*, Tom Good, Jessie Moravek, and Peter Kiffney

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Anadromous salmon can play a significant role in the trophic ecology of freshwater rivers in the Pacific Northwest. The purpose of this study was to investigate avian community metrics in relation to salmon density and habitat variables in the Cedar River, WA. To assess the potential effects of salmon on bird communities, we conducted bird strip surveys from July 6-17, 2015, along 4-5 100-m transects within 7 reaches (distinguished by river gradient and salmon density) of the Cedar River. We recorded the number, species, location relative to the river, and behavior of all birds observed, as well as habitat data (e.g., slope, number of available perches). Species richness was positively correlated with adult salmon input, and abundance, density, richness, and diversity were inversely related to channel slope. The results of this study assist in understanding the link between aquatic and terrestrial food webs.

ECOSYSTEM SCIENCE  
P-4

## Trends in the distribution, relative abundance, and population structure of the Pacific flatnose, *Antimora microlepis*, on the U.S. West Coast

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As fisheries managers attempt to incorporate ecosystem-based considerations into decision making processes, it is increasingly important to understand the role that non-target species play in the ecosystems that support commercial fisheries. For some bycatch species that occur in deep-water groundfish trawls, basic information on biology and population dynamics is extremely limited. This study presents findings on the spatial distribution, population structure, and relative abundance of the Pacific flatnose, *Antimora microlepis*, on the U.S. West Coast using data collected from 2003 to 2014 on the Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey (WCGBTS). We observed a 69% increase in mean fork-length over the study period reflecting the advancement of strong year-classes from the late 90s and early 2000s that currently dominate the population as a whole. Mean catch-weighted depth increased significantly as these cohorts moved to deeper waters of the continental slope. Although catch per unit effort remained relatively constant, this demographic shift suggests that episodic recruitment may significantly affect the abundance of this stock and its resilience to fishing mortality over time. We also report spatial variations by length, sex-frequency, and age.

ECOSYSTEM SCIENCE / SPECIES  
P-5

## Integration vs. Segregation: a “common garden” approach to understanding population level patterns of early male maturation in Columbia and Snake River Basin spring Chinook hatchery programs

Abby E. Fuhrman\*, Deborah L. Harstad, Brian R. Beckman, Donald A. Larsen

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Age of male maturation in spring Chinook salmon is plastic, and can occur as a precocious age 1 microjack, age-2 minijack or an age 3-5 anadromous adult. Harstad et al. (2014) conducted a comprehensive survey of minijack rates at various Columbia Basin salmon hatcheries and found minijack rates ranged from 8% to 71% of males released depending on facility. Moreover, they found that integrated programs, which use some prescribed percentage of natural origin broodstock for spawning, showed a positive correlation between early growth and minijack rate, whereas segregated programs that only spawn hatchery fish did not show the same trend. High rates of minijack production may have negative impacts on harvest and broodstock goals for hatchery programs and minijacks may have negative ecological interactions with native stocks. With these findings in mind, we designed a “common garden” rearing experiment to look for population level patterns and the relative influence of early growth rate on minijack rates in segregated vs. integrated stocks. During the fall of 2014, we collected 1500 eyed-embryos from several hatchery programs throughout the Columbia and Snake River Basins (10 families represented per stock) and transferred them back to the Northwest Fisheries Science Center research hatchery. The hatchery stocks, which included Winthrop (Methow), Rapid River (Snake), Carson (Wind), Pahsimeroi (Salmon), Sawtooth (Salmon) and Imnaha (Snake), had varying degrees of integration or segregation and some hatcheries had both. All fish were ponded on the same day in sixteen separate 4-ft tanks (2 replicates per hatchery group) and reared under identical growth rates for approximately 18 months. In spring of 2016 the proportion of males maturing as minijacks and the threshold size at maturity will be determined. Hypothesis and results to date will be presented.

SPECIES  
P-6



## Understanding relationships between biological population data and environmental variation for rockfish off the West Coast of the United States

Vladlena Gertseva\* and Sean E. Matson

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Environment has complex effects on spatial and temporal dynamics of marine fish species. Several assessments for one groundfish sentinel species (Darkblotched rockfish) reported noticeable year-to-year variability in size composition of the surveyed portion of the stock, with the most stark change observed during the 2014 warm anomaly. This variability had a pronounced effect of stock assessment results. Understanding how biological data such as length structure vary in relation to changing oceanographic conditions is critical for accurately interpreting results of the research surveys and assessing the status of our fisheries resources. We analyzed NMFS bottom trawl survey data on distribution and abundance of different Darkblotched size classes in relation to environmental factors, such as temperature, salinity and dissolved oxygen, and found that there are indications of size-specific habitat preferences in Darkblotched rockfish. To answer the question whether change in Darkblotched rockfish size composition is triggered by oceanographic conditions, we present our findings, propose several mechanisms to explain variability in Darkblotched rockfish size composition, and discuss the observed pattern in the context of the ecosystem dynamics.

**SPECIES**  
**P-7**

## Improving the information available for assessing and managing morphologically similar species: Vermilion rockfish (*Sebastes miniatus*) and its cryptic pair, sunset rockfish (*S. crocotulus*)

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Over the past 15 years, genetic research has identified several instances of incipient and cryptic speciation within the rockfishes (Genus: *Sebastes*) of the Eastern Pacific Ocean. Prominent examples include *S. ciliatus*, *S. aleutianus*, *S. miniatus*, *S. flavidus*, and *S. mystinus*. These discoveries present challenges for researchers and managers who must determine whether to assess and manage the component groups individually or as a complex. In the absence of detailed demographic information about the constituent species, the likely result is for the pair to be assessed collectively which can contribute bias or uncertainty to the analysis. This uncertainty can be of a magnitude that managers may ultimately decide to table significant changes in harvest rules and maintain status quo policies. Here, we examine *S. miniatus* and its cryptic pair, *S. crocotulus* using data collected from a fishery-independent hook and line survey in Southern California. This work expands on foundational research by the SWFSC which identified basic differences in the distribution and morphology of the two species. Our analysis uses survey data from 2004 - 2013 to compare the distribution, length-weight relationships, age and growth, and maturity patterns of the two groups with the objective of clarifying their biology and demographics and assisting stock assessors and managers determine the best approach for ensuring the sustainability of these important and valuable species.

SPECIES  
P-8

## Effects of modulating ration and dietary lipid on smolt quality and adult returns of Umatilla River yearling fall Chinook salmon

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The Umatilla River yearling Fall Chinook salmon hatchery program produces approximately 900,000 smolts annually. An estimated 42-79% of all observed returning males from this program return as minijacks. A production scale experiment was carried out to compare the standard feeding regime with other regimes incorporating modified lipid levels and feed rations in attempt to reduce minijack rates while maintaining acceptable adult returns. This 2x2 factorial experiment was conducted at Bonneville Hatchery, Oregon for brood years 2010-2013. Fish were fed High (18%) or Low (12%) fat diets at High (7days/week) or Low (4 days/week) ration levels April - November, after which all groups received the standard High Fat-High Ration diet until release in March. Fish size, gill ATPase activity, and % solid (surrogate for lipid) were monitored routinely during the experiment. Minijack rate was determined prior to release by measuring plasma 11-ketotestosterone. To evaluate post-release performance, all fish were coded-wire-tagged and a subset from each rearing group received PIT tags. Non-standard feed treatments successfully altered growth, lipid, smolting and minijack rate. Minijack rate was highest in the standard production (High-High) fish each year and lowest in the Low Lipid-Low Ration fish. Spring ATPase activity was consistently highest in the Low-Low fish. These data suggest that reducing growth rates and lipid accumulation through autumn reduced minijack rate and improved smolt development. Early trends in adult return data (BY 2010) show that diet manipulation reduced the numbers of minijacks and increased the proportion of fish returning at older age classes. In hatchery rearing, there are trade offs between producing large smolts to increase survival or reducing growth to lower early maturation. As more return data becomes available, we will have a better understanding of which rearing regime provides the optimal balance between these competing processes.

OTHER  
P-9

## Molecular sex differentiation in sablefish (*Anoplopoma fimbria*): gonadal gene expression patterns during normal sex differentiation and hormonal sex reversal

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Approaches for reproductive sterilization are needed for marine aquaculture to mitigate public concern associated with escapement of cultured animals and potential genetic contamination of wild stocks. To develop such approaches it is imperative to first have a sound understanding of how gonadal sex differentiation occurs naturally in marine fish. This study focused on characterization of molecular events occurring within gonads of sablefish (*Anoplopoma fimbria*) during this process and linking them to morphological changes associated with the formation of ovaries or testes. Next-generation sequencing was conducted on sablefish ovarian and testicular mRNA to obtain sequences for gene transcripts associated with vertebrate sex determination and differentiation. Expression patterns of selected genes, including key transcription factors, steroidogenic enzymes, gonadotropin receptors and transforming growth factors, were further analyzed in an ontogenetic/developmental series of sablefish by quantitative PCR. In addition, gonadal gene expression was analyzed in hormonally sex-reversed sablefish. Molecular sex differentiation was first observed in fish ~50 mm in length and preceded morphological differentiation of the gonads, which was first observed at ~80 mm. The earliest markers of testicular differentiation were a transcription factor, *dmrt1*, and transforming growth factor genes, *amh* and *gsdf*. The earliest markers of ovarian differentiation were the enzyme responsible for estrogen synthesis, *cyp19a1a*, and a gonadotropin receptor gene, *lhcg*. Elevated expression of several steroidogenic enzymes and receptors in differentiating testes relative to ovaries suggested early steroid production might be required for testis development. Interestingly, other genes like *figla* and *zpc* were ovary specific and demonstrated delayed onset of expression, increasing with the appearance and development of oocytes. Sex-reversed sablefish (confirmed by histology) reflected complete inversion of the sex-specific gonadal gene expression patterns. This study implicated particular genes in the process of sablefish sex differentiation and provided numerous biomarkers for future work aimed at inhibiting/blocking this process to induce sterility.

OTHER  
P-10

## A new approach to reproductive analysis for fisheries management, a Case Study on *Sebastes pinniger*

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Since the initiation of the NWFSC's reproductive maturity program (FRAM Division) in 2009, we have identified several key factors to understanding reproductive biology of west coast groundfishes. These include: (1) spatial and temporal patterns, (2) oceanographic conditions related to skip spawning and abortive maturation, and (3) estimating biological (sexual) versus functional (potential spawner) maturity. In the past many stock assessments have relied on outdated or incomplete life-history information from opportunistic or geographically/temporally limited data sources. Our goal is to provide updated, coast wide maturity information on an annual basis to reduce uncertainty in parameters used to estimate spawning biomass and recruitment. Ecosystem variables, such as habitat, predator-prey interactions, food availability, upwelling, and oceanographic patterns may also have an outsized influence on the reproductive behavior of groundfish stocks in a given year. We are investigating how these variables affect skip-spawning and abortive maturation patterns and how spatial/temporal relationships are associated with maturity schedules.

ECOSYSTEM SCIENCE  
P-11

## Life history differences between rougheye (*S. aleutianus*) and blackspotted (*S. melanostictus*) rockfishes based on genetic analysis

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Cryptic and incipient speciation within rockfishes (genus *Sebastes*) abounds on the U.S. West Coast. Investigation into morphological, life history, and genetic differences between similar species continues to reveal important distinctions among known species as well as within currently recognized species. Ambiguity in the taxonomy and biology of such species may result in historical data being pooled inappropriately, potentially obscuring important life history differences and adding uncertainty to stock assessments. We identify differences in the depth, spatial distribution, and growth for the rougheye (*S. aleutianus*)/blackspotted (*S. melanostictus*) complex while also offering preliminary results into newly discovered genetic variability within darkblotched rockfish (*S. crameri*).

The West Coast Groundfish Bottom Trawl Survey, At-Sea Hake Observer Program, and Oregon Department of Fish and Wildlife provided over 900 tissue samples for the rougheye/blackspotted genetic analysis. The process employed a diagnostic Taqman assay of the ND3 mitochondrial region developed for this species pair. Morphometrics and meristics confirm these species are challenging to distinguish via visual diagnostics, but are definitively identifiable using genetic techniques. Results indicate over 15% of the catch previously considered as nominal rougheye rockfish may be blackspotted. These results have implications for long-term data sets including commercial landings and historical survey data.

Color variability in darkblotched rockfish has elicited a similar investigation into stock structure. Preliminary analysis suggests consistent genetic variation among samples at multiple loci. However, voucher specimens examined to date have thus far not revealed a connection between observed genetic differences and various morphometric and meristic characteristics. Further investigations are underway.

SPECIES  
P-12

## Population genetic structure of wild steelhead in central Idaho suggests gene flow directly between headwaters of the upper Salmon River and Middle Fork

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We have an ongoing genetic monitoring program in Central Idaho's Salmon River Basin to evaluate population genetic structure and potential changes in diversity of *Oncorhynchus mykiss* populations for the benefit of threatened steelhead recovery efforts. An overall pattern of genetic delineation between major drainages persists in the Salmon Basin, though an exception was found between two headwater populations: Marsh Creek in the Middle Fork headwaters was genetically similar to Valley Creek, a tributary of the upper Salmon River main stem. The known waterway distance between these sites is roughly 500 km but the geographic distance is less than 200 m across a marshy meadow at Blind Summit, Idaho. Both population-level genetic analyses and model-based clustering indicate recent gene flow. Apparently, this area is subjected to periodic local flooding during spring snowmelt that could intermittently allow short distance access to Marsh Creek by Valley Creek fish. In this study, we describe specific patterns of isolation by distance with the exception presented. Our results are relevant to recovery and conservation of Salmon River steelhead as well as the broader understanding of population genetics and phylogeography of salmon and steelhead throughout the Pacific Northwest.

SPECIES  
P-13

## Life after precocious male maturation in a semelparous salmonid: a physiological perspective in spring Chinook salmon

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Atlantic salmon are iteroparous; possessing the ability to undergo repeat sexual maturation. Precociously mature males of this species (a.k.a “precocious parr”) are also capable of smoltification and/or rematuration following maturation at age-1. Pacific Chinook salmon are typically characterized as semelparous; dying after a single lifetime spawning event. However, observations of survival following maturation in males that mature at age-1 (a.k.a. “microjacks”) have been documented, but little is known regarding the post maturation physiology of these fish. Specifically, it is unclear the degree to which they may either die, undergo testicular resorption and smolt (prepare for ocean entry) or remature. Furthermore, if all these life-history options are possible in a population, in what proportions do they occur under variable environmental conditions? In order to answer these questions in this investigation we measured a series of physiological factors including (survival rate, size, gill Na<sup>+</sup>/K<sup>+</sup>-ATPase activity, plasma 11-KT, whole body lipid, pituitary FSH and LH mRNA, GSI, and testicular histology) in fish following maturation at age-1 that were fed either a high or low winter ration until age-2. We determined that well-fed microjacks were much more iteroparous than semelparous. Ration challenged microjacks very rarely die and almost all remature. There was no evidence that microjacks resorbed their testes and smolt under high or low ration. Approximately 50% of all fish were bloated requiring milt expression and most mortality, when it did occur, appeared to be related to this condition. Thus, having “sneak” spawning opportunities with anadromous females may enhance survival of microjacks in the natural environment.

SPECIES  
P-14



## A dockside sampling program for integrating high resolution genetic information into fishery management

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Project CROOS and the West Coast Salmon Genetic Stock Identification Collaboration (WCSGSI), [www.pacificfishtrax.org](http://www.pacificfishtrax.org), have been engaging fishermen to sample Chinook salmon at sea in Washington, Oregon, and California fisheries since 2006 to explore the feasibility of using fine-scale sampling and genetic techniques in ocean management of Chinook salmon commercial troll fisheries. Until now, sampling has been conducted by a few select fishermen operating in limited times and areas, and paid per sample. Expansion of these data to represent the full fishery is not possible. Transition to fisheries management is expected to require development of a sampling system that is: 1) compatible with current dockside sampling; 2) enables a stratified sample representative of the fishery; and 3) is cost-effective while maintaining the fine-scale catch and effort information currently being collected. This summer we will equip fishermen with tablets for electronic data collection at sea. Fishermen will use the tablets to log their fishing tracks and catch locations. Every Chinook salmon captured will be assigned a barcode tag, and the location and depth recorded. At the dock, a port sampler will select fish to measure and sample for GSI and scales following an established protocol to minimize sampling bias and maximize random selection of samples. CWTs will be sampled concurrently. Development of “management-friendly” sampling techniques is one of the principle impediments to adoption of fine-scale genetics-based information in fishery management. The ability to collect and interpret high-density catch and effort data based on GSI has been demonstrated. Development of an operational sampling methodology may enable a transition in fishery management, with the potential to improve the timeliness and quality of information available to sustain harvest while reducing bycatch of weak stocks.

**SPECIES**  
**P-15**

## Effect of point source feeders on cultured sockeye salmon social behavior

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The study examines the effect of a point source food supply on the social behavior of sockeye salmon (*Oncorhynchus nerka*) reared in a conservation hatchery setting. The three treatments consisted of a control in which fish were not fed, an experimental treatment in which fish were fed using point source automated feeders and an experimental treatment in which fish were hand fed. Each replicate consisted of placing three fish in a 3.6 m grey circular tank, allowing them overnight to recover from the effects of handling, and starting at 0900 the next morning photographing them at half hour intervals until 13 photographs were acquired. The photographs were examined for grouping, mean angle between fish and mean distance between fish. General observations made over the course of the study and analysis of the photographic data indicate Snake River sockeye salmon vary their social behavior from solitary to paired to aggregated to schooled and the presence of a point source food supply increases aggression, but does not elicit territorial defense.

SPECIES  
P-16

## Urban runoff differentially affects coho and chum salmon spawners

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In areas of the Salish Sea watershed with elevated vehicular traffic density, stormwater runoff causes pre-spawning mortality (PSM) in adult coho salmon (*Oncorhynchus kistutch*). Within a few hours of exposure, symptoms progress from lethargy and disorientation to loss of equilibrium, immobility, and eventually death. Although we do not know the precise cause of PSM, we previously determined that coho PSM is linked to storm events. Chum salmon (*O. keta*) spawning runs often overlap with coho. To determine whether chum are similarly susceptible to PSM, we co-exposed pre-spawn adult coho and chum to urban road runoff or well water in controlled exposures for 6 storm events. We monitored water quality and individual behavior throughout exposure. Exposures were terminated after 4 h or when fish became symptomatic. Only coho exposed to runoff became symptomatic. Across the 4-h exposure, chum appeared behaviorally unaffected by urban runoff. Furthermore, we employed a point-of-care blood analysis tool to measure a variety of blood parameters including ion concentrations and gases, pH, hematocrit, glucose, and lactate. Multiple blood chemistry parameters were affected in runoff-exposed coho compared to control coho. In contrast, chum exposed to runoff were much less sensitive than controls.

SPECIES  
P-17

## The influence of salmon recolonization on riparian communities in the Cedar River, Washington, USA

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Salmon are a valuable resource throughout the Pacific Northwest, and salmon conservation efforts often focus on the re-colonization of salmon into historically obstructed areas such as the Cedar River in Washington, USA. However, to assess the implications of salmon re-colonization, it is critical to consider not only the river ecosystem but also the surrounding riparian habitat. To investigate connections between salmon and the riparian habitat in the Cedar River after 12 years of re-colonization, we identified spiders, collected prey from spider webs, and characterized aquatic macroinvertebrates along a gradient of salmon inputs ( $\text{g}/\text{m}^2$ ). We found that the density of aquatic macroinvertebrates and spider prey increased and spider diversity decreased with salmon inputs, suggesting that salmon provide energy for aquatic and riparian food webs and lead to specialization in spider communities. The connection between salmon and riparian habitats is compelling motivation for further studies regarding aquatic-riparian linkage on the Cedar River.

ECOSYSTEM SCIENCE  
P-18

## Developing a non-invasive method to assess green sturgeon (*Acipenser medirostris*) condition

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Non-invasive methods to determine sturgeon condition are needed for both aquaculture and sturgeon conservation. Our aim was to determine whether a Distell fish fatmeter could be used for reliable assessment of green sturgeon condition. There is no documented use of this technology with sturgeon species. To establish the relationship between lipid content and fatmeter reading, we conducted a laboratory experiment on green sturgeon held in captivity at the Conte Anadromous Fish Research Center. Thirty sexually-immature sturgeon (age 8, total length 75.1 - 114 cm, weight 1.9 - 7.4 kg) were held in Connecticut River water at 14°C, and under five different feeding rates: 0.1%, 0.25%, 0.5%, 1.0%, 1.5% of body weight/d. All experimental sturgeon carried a previously implanted Passive Integrated Transponder (PIT) that provided unique identification. We conducted proximate composition analysis on muscle tissue of sacrificed animals, along with fatmeter readings, after 167-169 days. Muscle fat content was determined via supercritical fluid extraction (SFE) using carbon dioxide and an ethanol modifier. Five fatmeter measurements were taken at each of three different sites along the dorsal flank above the lateral line. For all treatments, mean total length increased between the initial sample and the end of the experiment. However, fish fed the lowest ration decreased in mean weight and condition factor. As expected, hepatosomatic index (liver weight /body weight x100 %) increased with feeding ration. Additionally, muscle protein content was positively correlated with ration, and inversely correlated with muscle moisture content. In spite of a wide range of resulting individual muscle lipid levels (0.5 – 3.4%), the fatmeter readings did not accurately reflect flesh lipid content, regardless of the position on the sturgeon body where they were taken. Further refinement of this technology is needed if it is to be used on sturgeon either in aquaculture settings or in the wild.

SPECIES  
P-19

## Prevalence of pathogens in Pacific Lamprey of the Pacific Northwest

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In the Columbia River Basin, supplementation of Pacific Lamprey is an emerging recovery tool for this imperiled species. To manage disease risk at prospective lamprey hatcheries, an understanding of the pathogens and parasites most associated with lamprey is critical. Toward this end, we assembled regional fish health data for assessments of pathogen prevalence for 794 Pacific Lamprey sampled from various sources. Of the 518 adults examined, 299 were from tribal holding facilities. Pathogen prevalence in adults was low; but *Aeromonas salmonicida* was regularly identified in fish that had died and were submitted for health screening. Larval lamprey exhibited very low pathogen prevalence, and larvae challenged with *A. salmonicida* showed no infection or mortality. Detailed health assessments for metamorphosed juveniles (*macrophthalmia*) were conspicuously lacking. However, external examinations of over 20,000 *macrophthalmia* captured at dams on the lower Columbia River indicated that they are susceptible to fungal infection, particularly in warm water conditions. To fully evaluate the disease risk associated with lamprey supplementation, directed research is needed along with standardized health screenings of lamprey at all life stages. Our review of existing data suggests that control of *A. salmonicida* will be a top priority, as this was the only pathogen regularly identified in Pacific Lamprey samples collected throughout the Columbia River Basin.

SPECIES  
P-20

## Sustainable feeds from fish waste for aquaculture

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The work presented addresses the use of fish processing trimmings to make and test fish feed using a new process based on a heated ball mill developed at the Northwest Fisheries Science Center. The goal is to increase the supply, quality, and diversification of domestic seafood through development of alternative feed sources that reduce the demand for fishmeal from limited supplies of industrial forage fish. Work to date includes efficiently making feeds from numerous fish trim sources to add value to the fish waste and using the feeds to grow fish to quantify the performance and value of the experimental feeds. Results have demonstrated feed performance equal or better than commercial feeds and process economics that make this an alternative to current fish trim processing technologies that are too expensive to serve many small or remote fish processors.

SEAFOOD SAFETY  
P-21

## Long term cardiotoxic effects of embryonic crude oil exposure in fish

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It is well established that oil spill toxicity can specifically target the developing heart of fish embryos, and that early cardiotoxic effects occur similarly across a variety of fish species. Zebrafish have been used as a laboratory model to begin to assess the potential long-term effects of sublethal oil exposure. Adult zebrafish that were transiently exposed to oil as embryos were shown to have subtle but significant changes in heart shape, as well as significantly reduced cardiac output/swimming performance. These findings informed subsequent experimental exposures using pink salmon and Pacific herring – two important commercial species that were heavily impacted by the Exxon Valdez spill. These fish were evaluated at the juvenile stage after transient embryonic oil exposure, and also were found to exhibit changes in cardiac shape and reduced swimming performance. The focus of current research incorporates cardiac gene expression analysis to assess the long-term molecular effects of oil exposure. This molecular information will be used to explore potential mechanistic links between select genes and oil-induced changes in cardiac morphology or performance, and to aid in the pursuit of molecular markers of oil exposure at later life stages.

SPECIES  
P-22

## AquaTracker: A tool for the analysis of acoustic telemetry data

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Acoustic telemetry has become an important tool in fisheries research. Information from acoustic telemetry studies is used in fisheries science to define habitat ranges, migratory routes, foraging areas, home ranges, and to estimate survival of anadromous species at various points along their seaward migration. Acoustic arrays generate massive amounts of data. The lack of software designed for data reduction, analysis, and visualization of acoustic array data has hampered the dissemination of study results. We developed a program, AquaTracker, to quantify, analyze, and visualize the data generated by steelhead trout (*Oncorhynchus mykiss*) in Puget Sound. The program, AquaTracker, can plot a fish path as a graph or animate the path and export it as a movie. The program can plot a valid path around land-masses. AquaTracker can also calculate travel rate, distance, range, path linearity, and many other track parameters. Pre-analysis tools include identifying receivers with overlapping radii and singleton detections. The program is a self-contained application that works well in Windows XP thru Windows 8. The installation package includes extensive documentation and supporting software for importing data from a variety of sources.

ECOSYSTEM SCIENCE  
P-23

## Implications of management and dynamic climatic conditions for the recovery of Snake River sockeye

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North America's southernmost sockeye salmon population from Idaho's Salmon River basin has partially recovered from near extinction in the 1990s due to a captive broodstock and hatchery supplementation program, improved natal habitat, and improved riverine and ocean conditions. Significant challenges remain in completing this recovery for both juveniles and adults as dramatically demonstrated this past summer. While record returns were realized for this population to the Columbia River, very low river flows and high water temperatures substantially impacted further migration and survival to spawning.

We utilized passive integrated transponder (PIT)-tag technology to individually follow sockeye salmon and examine overall migration and survival as well as cohort differences in rearing strategies, release protocols, and barge transport vs in-river migration. With recent adult return increases, we have also estimated adult upstream migration timing and survival and compared population-cohorts in the common migration reach from Bonneville Dam (BON) to McNary Dam (MCN).

Results showed interesting patterns using migration years 2008-2013 data: 1) Smolt-to-Adult return percentage (SAR) from Lower Granite Dam (LGR) to BON was annually variable (0.2 to 3.7%); 2) Sawtooth Hatchery had 75% lower SAR than Oxbow Hatchery presumably related to smaller release size; 3) juvenile transportation had 75% higher LGR-BON SAR than in-river migration; 4) BON-LGR adult survival was highly variable (4-75%) averaging 23% and 43% for juvenile-transported and in-river fish, respectively (2013 at only 4 and 16% due to extreme conditions this summer) and often seasonally decreasing; 5) therefore, juvenile transportation had 17% lower LGR-LGR SAR than in-river migration; 6) omitting transported fish, Salmon River adult fish had lower BON-MCN survival than upper Columbia fish (averaged 10% but was 35% this summer).

These results indicate this sockeye salmon population can respond positively to recovery efforts but is quite sensitive to anthropomorphic and climate effects.

**SPECIES**  
**P-24**



## Effect of taurine deficient diet on olfactory function and possible conservation of taurine in sablefish (*Anoplopoma fimbria*)

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Development of alternative, terrestrial plant-based feeds raises important nutritional issues. Several nutrients present in fish meal are absent in plant proteins, including taurine. Taurine plays an important role in many physiological processes including growth and olfaction. The sense of smell is important to fish, connecting them to the environment by relaying chemical information that plays a role in triggering behaviors associated with feeding, predator avoidance, reproduction and migration.

Electrophysiological techniques make it possible to measure physiological olfactory responses to various substances. Some amino acids are important stimulants of searching and feeding behaviors. Olfactory sensitivity to different amino acids has been shown in fish and varies among species. Using the electro-olfactogram (EOG) and the electroencephalogram (EEG), it is possible to measure the neurological responses to amino acids at the receptor sites in the nose and the olfactory bulb. In this way, if the olfactory response in fish is affected by a lack of taurine in the diet, it should be possible to demonstrate that change using these techniques.

Two studies were conducted with fish maintained on plant-based feeds supplemented either with taurine at 1 or 1.5%, or with no taurine or a commercial feed as a reference. Results of the initial experiment indicated a potential reduction in olfactory function in the olfactory bulb, presumably in response to taurine deficiency. Initial analysis of the larger follow up study may show a similar reduction in olfactory function (Fig. 1). Fish in this experiment however were maintained in a recirculating system as opposed to the flow-through system used in the initial experiment. Individual growth, olfactory function and whole body taurine levels were traced by individually marking fish with PIT tags. Whole body taurine levels of fish fed the 0 taurine diet averaged .1%, about half the level of fish that received the 1% taurine diet. Results of the follow up study indicate that taurine is either conserved, synthesized by sablefish, or possibly that fish are able to absorb taurine from culture water.

SEAFOOD SAFETY  
P-25

## Northwest Fisheries Science Center Economic Data Collection Program for Catch Shares

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In January 2011, the West Coast Limited Entry Groundfish Trawl fishery transitioned to the West Coast Groundfish Trawl Catch Share Program. In order to monitor the economic effects of the catch share program, the annual Economic Data Collection Program collects information on operating costs, revenues, and vessel and processing facility characteristics. These data serve as the basis for several of the talks that will be presented at this meeting. We designed a suite of infographics to convey a high-level view of the Catch Share Program and highlight the types of information found in our more detailed annual reports. This is a rich data source that can assist other government researchers, fisheries managers, non-governmental organizations, industry, and the general public understand the changes resulting from the implementation of this new management program. These infographics serve as an excellent starting point for understanding the catch share program and the data available for further research.

OTHER  
P-26

## Exploring an individual based modeling approach in fisheries

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Much fishery modeling is focused on the average characteristics of a population and simulates the rates of survival or mortality, or changes in population size in terms of the population as a whole. The underlying support for these models comes from the mathematics associated with linear algebra and differential equations. Stock Synthesis is a well-known example of this type of top-down approach.

In contrast, an individual based model (IBM) is a bottom-up approach that allows emergent properties of a system to arise from individual contributions. A model of this type features a simulation framework in which individual organisms are tracked in time; these individuals may be subject to environmental forcing and to anthropogenic pressure (e.g., fishing). The responses of interest may range from survival to the evolution of genetic traits, while the timeframe of interest may range from days to decades.

Programming approaches and platforms necessary for IBMs are not necessarily the ones we find most convenient. Much modeling in fisheries (and in ecology generally) is done using interpreted or scripted languages such as Matlab, R or Python. These languages offer such benefits as integrated statistical and graphical environments which makes them are very good tools for fast prototyping. However, tracking the fates of millions of individuals requires high-performance computing, and thus individual based models are often implemented in C/C++, Java, or Fortran.

I present the results of an individual based model that evaluates intergenerational genetic drift in individual growth parameters in response to a variety of fishery management practices.

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